



1

**TOOLBOX**

## Detección Autónoma y Temprana de Fallas: Una Solución Predictiva en Base a Inteligencia Artificial

**Enrique López Droguett**

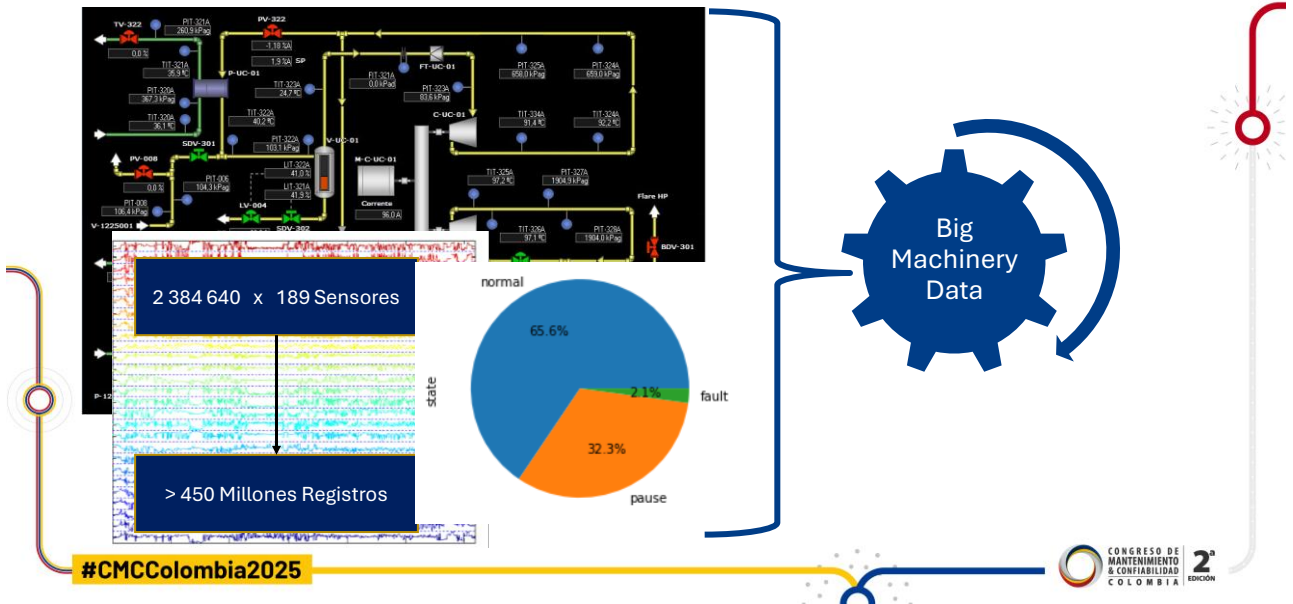
Profesor Titular – Department of Civil & Environmental Engineering, University of California, Los Angeles (UCLA)

Profesor Titular – Departamento de Ingeniería Mecánica, Universidad de Chile



2

## Big Machinery Data



3

## Recuperación de Gases de Hidrocarburos

SCADA Data:

|         | Tline               | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | ... | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A | P74_P25-1225032A |
|---------|---------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-----|------------------|------------------|------------------|------------------|------------------|
| 0       | 2019-05-15 16:00:00 | 95.833038        | 41.875732        | 29592.986328     | 28.496231        | 31.000000        | 31.308243        | 88.832901        | 616.877563       | 31.754730        | ... | 8.860001         | 277.799927       | NaN              | NaN              | NaN              |
| 1       | 2019-05-15 16:00:15 | 96.658127        | 41.875732        | 29652.853516     | 28.499142        | 31.393305        | 31.956072        | 89.634567        | 617.388550       | 31.754730        | ... | 8.860001         | 277.799927       | NaN              | NaN              | NaN              |
| 2       | 2019-05-15 16:00:30 | 97.429520        | 41.875732        | 29709.990234     | 28.499142        | 32.000000        | 32.232456        | 90.324455        | 616.597107       | 31.754730        | ... | 8.860001         | 277.799927       | NaN              | NaN              | NaN              |
| 3       | 2019-05-15 16:00:45 | 96.560219        | 41.875732        | 29651.580078     | 28.499142        | 31.393305        | 31.956072        | 89.634567        | 617.388550       | 31.754730        | ... | 8.860001         | 277.799927       | NaN              | NaN              | NaN              |
| 4       | 2019-05-15 16:01:00 | 97.439282        | 41.875732        | 29738.400391     | 28.499142        | 32.000000        | 32.232456        | 90.324455        | 616.597107       | 31.754730        | ... | 8.860001         | 277.799927       | NaN              | NaN              | NaN              |
| ...     | ...                 | ...              | ...              | ...              | ...              | ...              | ...              | ...              | ...              | ...              | ... | ...              | ...              | ...              | ...              | ...              |
| 1000912 | 2019-12-30 10:22:45 | 111.416844       | 42.281544        | 0.000000         | 29.499142        | 31.393305        | 31.956072        | 89.634567        | 617.388550       | 31.754730        | ... | 8.860001         | 277.799927       | NaN              | NaN              | NaN              |
| 1000913 | 2019-12-30 10:23:00 | 112.089978       | 42.383545        | 0.000000         | 29.499142        | 31.393305        | 31.956072        | 89.634567        | 617.388550       | 31.754730        | ... | 8.860001         | 277.799927       | NaN              | NaN              | NaN              |
| 1000914 | 2019-12-30 10:23:15 | 113.051933       | 42.833439        | 0.000000         | 30.347029        | 33.389408        | 32.303215        | 66.353065        | 598.892090       | 38.435693        | ... | 8.860000         | 295.799927       | NaN              | NaN              | NaN              |
| 1000915 | 2019-12-30 10:23:30 | 124.350006       | 43.593155        | 0.000000         | 30.902191        | 32.675262        | 32.000000        | 124.350006       | 802.238159       | 39.743164        | ... | 8.860000         | 295.799927       | NaN              | NaN              | NaN              |

- Sensores: 188
- Registros > 450 millones
- Tasa de Muestreo: 15 seg
- Periodo: 1 año

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Recuperación de Gases de Hidrocarburos

Registros Detenciones:

|     | Start               | Finish              | LABEL          | OBS 1        |
|-----|---------------------|---------------------|----------------|--------------|
| 0   | 2019-02-07 21:50:00 | 2019-02-08 04:31:00 | Normal Stop    | Gen_Stand-by |
| 1   | 2019-02-08 14:03:00 | 2019-02-09 17:05:00 | Normal Stop    | Gen_Stand-by |
| 2   | 2019-02-16 05:45:00 | 2019-02-16 13:59:00 | Normal Stop    | Gen_Stand-by |
| 3   | 2019-03-01 05:45:00 | 2019-03-01 13:59:00 | Normal Stop    | Gen_Stand-by |
| 4   | 2019-03-01 14:03:00 | 2019-03-02 17:05:00 | Normal Stop    | Gen_Stand-by |
| ... |                     |                     |                | ...          |
| 122 | 2019-12-24 19:50:00 | 2019-12-25 08:22:00 | Unknown Cause  | Gen_Failure  |
| 123 | 2019-12-25 09:13:00 | 2019-12-25 09:51:00 | Unknown Cause  | Gen_Failure  |
| 124 | 2019-12-25 10:59:00 | 2019-12-25 13:29:00 | Unknown Cause  | Gen_Failure  |
| 125 | 2019-12-25 15:07:00 | 2019-12-30 10:24:00 | External Cause | Gen_External |
| 126 |                     |                     |                |              |

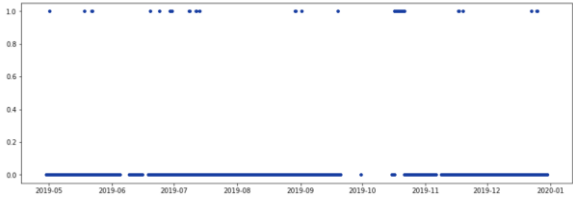
- Detenciones: 127
- Distintas causas
- Sincronizar data SCADA con registros detenciones

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Recuperación de Gases de Hidrocarburos

|                       | value counts | normalized value counts |
|-----------------------|--------------|-------------------------|
| External Cause        | 90           | 0.708661                |
| Normal Stop           | 13           | 0.102362                |
| Scrubber High Level   | 6            | 0.047244                |
| Instrument Failure    | 6            | 0.047244                |
| Electrical Failure    | 4            | 0.031496                |
| Unknown Cause         | 4            | 0.031496                |
| Mecanical Failure     | 3            | 0.023622                |
| High Suction Pressure | 1            | 0.007874                |

|   | value counts | normalized value counts |
|---|--------------|-------------------------|
| 0 | 1115196      | 0.967404                |
| 1 | 37576        | 0.032596                |



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## El Desafío: Inteligencia Artificial y Big Data

**Empresas que sigan ignorando la IA o descuiden su integración en sus organizaciones dejarán de ser competitivas**

**Se ahogarán en datos y complejidad**

**El mundo se basa cada vez más en datos**

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## IA en Confiabilidad y Mantenición Predictiva

**Desarrollar modelos predictivos para maximizar la vida de activos, eficiencia operacional o uptime**

**Aprovechar datos pasados y continuos**

**Optimizar las acciones de mantenimiento periódico**

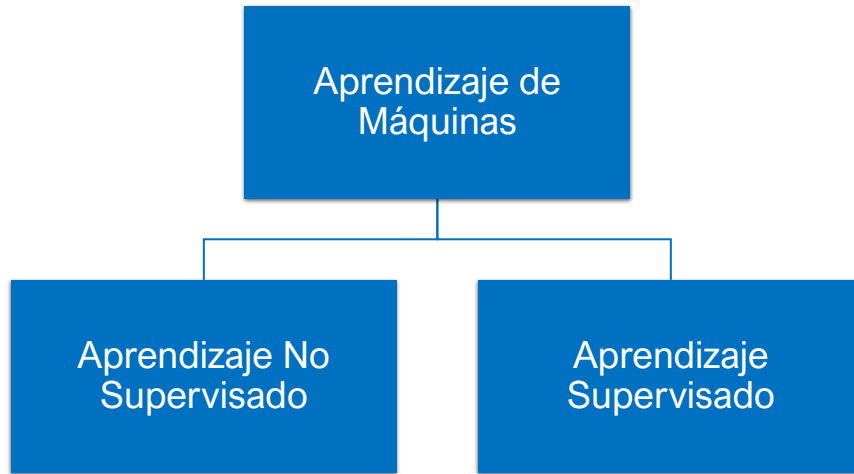
**Evitar o minimizar los tiempos de inactividad. Esto ayudará a evitar clientes insatisfechos y bajar costos**

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# Tipos de Aprendizaje de Máquinas



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## Aprendizaje No Supervisado

Data de Monitoreo: sensores, imágenes, tribología, informes ...

|         | Time                | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | ... | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A | P74_P12-<br>1225322A |
|---------|---------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-----|----------------------|----------------------|----------------------|----------------------|
| 0       | 2019-05-15 16:00:00 | 95.833038            | 41.875732            | 29592.986328         | 28.496231            | 31.000000            | 31.308243            | 88.832901            | 616.877563           | 31.754730            | ... | 8.860001             | 277.799927           | NaN                  | NaN                  |
| 1       | 2019-05-15 16:00:15 | 96.458127            | 41.875732            | 29652.853516         | 28.699142            | 31.393305            | 31.956072            | 89.434567            | 617.388550           | 31.754730            | ... | 8.860001             | 277.799927           | NaN                  | NaN                  |
| 2       | 2019-05-15 16:00:30 | 97.429520            | 41.875732            | 29709.990234         | 28.699142            | 32.000000            | 32.232456            | 90.324455            | 616.597107           | 31.754730            | ... | 8.860001             | 277.799927           | NaN                  | NaN                  |
| 3       | 2019-05-15 16:00:45 | 96.560219            | 41.875732            | 29651.580078         | 28.699142            | 31.602581            | 32.261463            | 89.555397            | 617.476562           | 31.754730            | ... | 8.860001             | 277.799927           | NaN                  | NaN                  |
| 4       | 2019-05-15 16:01:00 | 97.439282            | 41.875732            | 29738.400391         | 28.518536            | 31.896614            | 32.698605            | 90.579659            | 616.315552           | 31.754730            | ... | 8.860001             | 278.200073           | NaN                  | NaN                  |
| ...     | ...                 | ...                  | ...                  | ...                  | ...                  | ...                  | ...                  | ...                  | ...                  | ...                  | ... | ...                  | ...                  | ...                  | ...                  |
| 1000912 | 2019-12-30 10:12:45 | 111.414844           | 42.281544            | 0.000000             | 29.777554            | 34.111256            | 33.300499            | 66.124771            | 594.327087           | 37.584270            | ... | 8.560000             | 295.799927           | NaN                  | NaN                  |
| 1000913 | 2019-12-30 10:13:00 | 112.080978           | 42.383545            | 0.000000             | 29.882183            | 33.947151            | 33.000000            | 66.581305            | 594.532166           | 37.809132            | ... | 8.560000             | 295.799927           | NaN                  | NaN                  |
| 1000914 | 2019-12-30 10:13:15 | 113.051933           | 42.83439             | 0.000000             | 30.347029            | 33.389408            | 32.303215            | 66.353065            | 598.892090           | 38.435693            | ... | 8.560000             | 295.799927           | NaN                  | NaN                  |
| 1000915 | 2019-12-30 10:13:30 | 124.350006           | 43.593155            | 0.000000             | 30.992191            | 32.675262            | 32.000000            | 124.350006           | 802.238159           | 39.743164            | ... | 8.560000             | 295.799927           | NaN                  | NaN                  |

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# Aprendizaje Supervisado

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|      | rms      | peak     | peak-peak | crest    | median    | var      | skewness  | kurtosis | band_0   | band_1   | band_2   | band_3   | band_4   | band_5   | band_6   | band_7   | Estado Salud       |
|------|----------|----------|-----------|----------|-----------|----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|--------------------|
| 0    | 0.008641 | 0.028054 | 0.113452  | 3.246508 | -0.000770 | 0.000074 | -0.936986 | 7.808622 | 0.000443 | 0.000087 | 0.000088 | 0.000072 | 0.000072 | 0.000071 | 0.000072 | 0.000070 | Normal             |
| 1    | 0.011839 | 0.061926 | 0.122331  | 5.230773 | 0.002927  | 0.000132 | 0.099689  | 3.414683 | 0.000588 | 0.000057 | 0.000065 | 0.000042 | 0.000040 | 0.000038 | 0.000041 | 0.000039 | Daño Pista Externa |
| 2    | 0.007119 | 0.025424 | 0.084843  | 3.571287 | -0.000669 | 0.000050 | -0.408117 | 2.440640 | 0.000352 | 0.000055 | 0.000054 | 0.000046 | 0.000046 | 0.000043 | 0.000045 | 0.000045 | Daño Pista Externa |
| 3    | 0.008695 | 0.029699 | 0.070373  | 3.415453 | 0.002095  | 0.000071 | 0.023378  | 0.011527 | 0.000423 | 0.000059 | 0.000065 | 0.000040 | 0.000037 | 0.000035 | 0.000036 | 0.000036 | Daño Pista Externa |
| 4    | 0.033719 | 0.178666 | 0.307143  | 5.298701 | 0.000155  | 0.001137 | 0.190877  | 1.586085 | 0.001905 | 0.000158 | 0.000320 | 0.000088 | 0.000055 | 0.000053 | 0.000054 | 0.000052 | Daño Pista Interna |
| ...  | ...      | ...      | ...       | ...      | ...       | ...      | ...       | ...      | ...      | ...      | ...      | ...      | ...      | ...      | ...      | ...      | ...                |
| 1791 | 0.011743 | 0.045812 | 0.102929  | 3.901169 | 0.002555  | 0.000131 | -0.590345 | 2.556906 | 0.000589 | 0.000063 | 0.000065 | 0.000035 | 0.000034 | 0.000033 | 0.000034 | 0.000033 | Daño Pista Externa |
| 1792 | 0.009386 | 0.029041 | 0.090762  | 3.094046 | -0.000887 | 0.000087 | -0.167848 | 0.910860 | 0.000510 | 0.000070 | 0.000089 | 0.000058 | 0.000054 | 0.000053 | 0.000054 | 0.000054 | Normal             |
| 1793 | 0.005654 | 0.017531 | 0.064454  | 3.100641 | -0.000967 | 0.000031 | -0.486815 | 2.291622 | 0.000267 | 0.000046 | 0.000043 | 0.000034 | 0.000037 | 0.000034 | 0.000035 | 0.000036 | Normal             |
| 1794 | 0.036331 | 0.229967 | 0.449863  | 6.329757 | 0.001467  | 0.001318 | -0.396902 | 5.076555 | 0.002164 | 0.000181 | 0.000188 | 0.000051 | 0.000038 | 0.000036 | 0.000036 | 0.000036 | Daño Pista Interna |
| 1795 | 0.051150 | 0.339144 | 0.588965  | 6.630360 | 0.001024  | 0.002615 | -0.103091 | 2.720984 | 0.002809 | 0.000439 | 0.000338 | 0.000089 | 0.000059 | 0.000057 | 0.000057 | 0.000053 | Daño Pista Interna |

1796 rows x 17 columns

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## Estrategias en Soluciones Predictivas

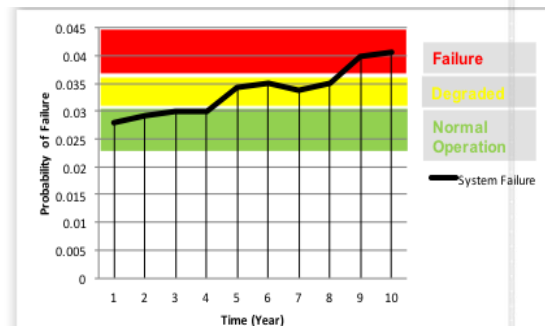
UCLA

Detección de Anomalías

Diagnóstico de Estados de Salud

Pronóstico de Estados de Salud

Predicción del Tiempo de Vida Remanente

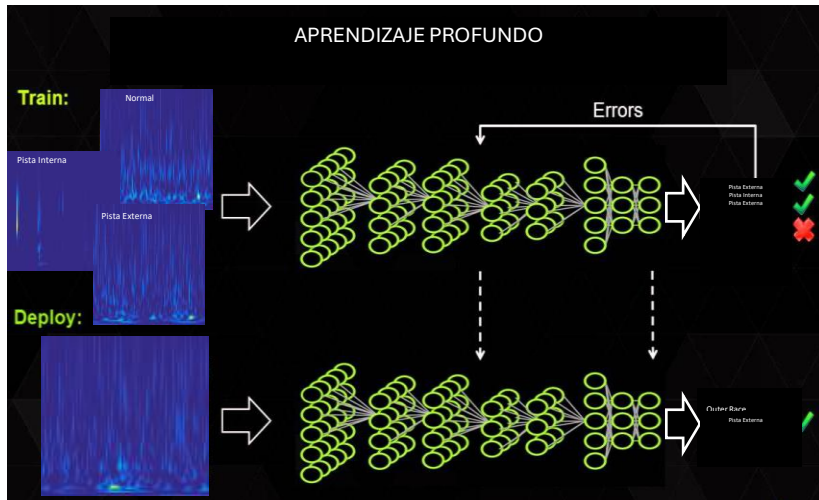


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## ¿Cómo? IA y Aprendizaje Profundo

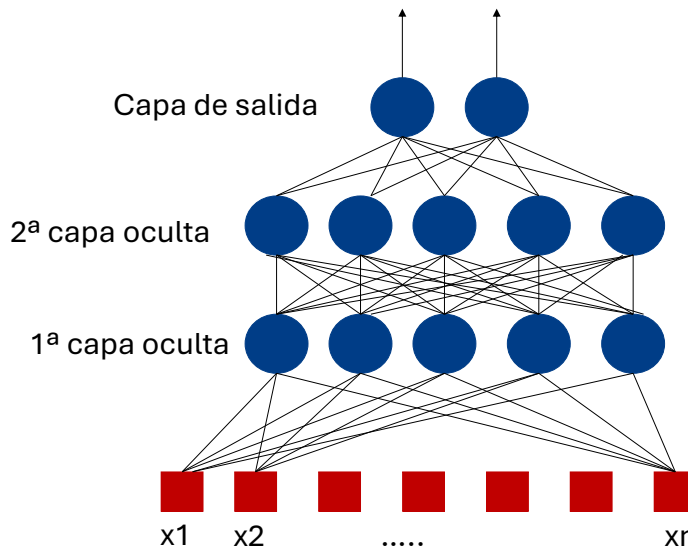


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## Redes Neuronales Profundas

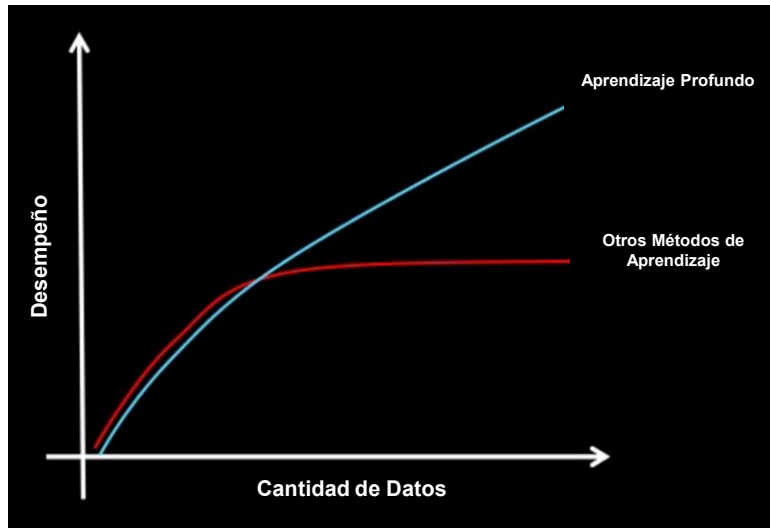


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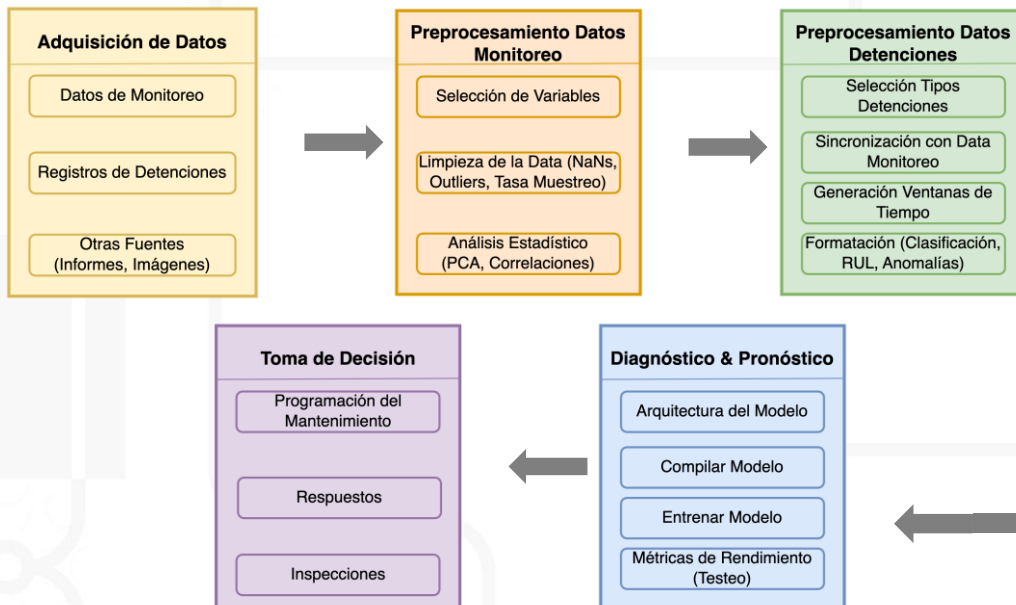
## ¿Por Qué Aprendizaje Profundo?



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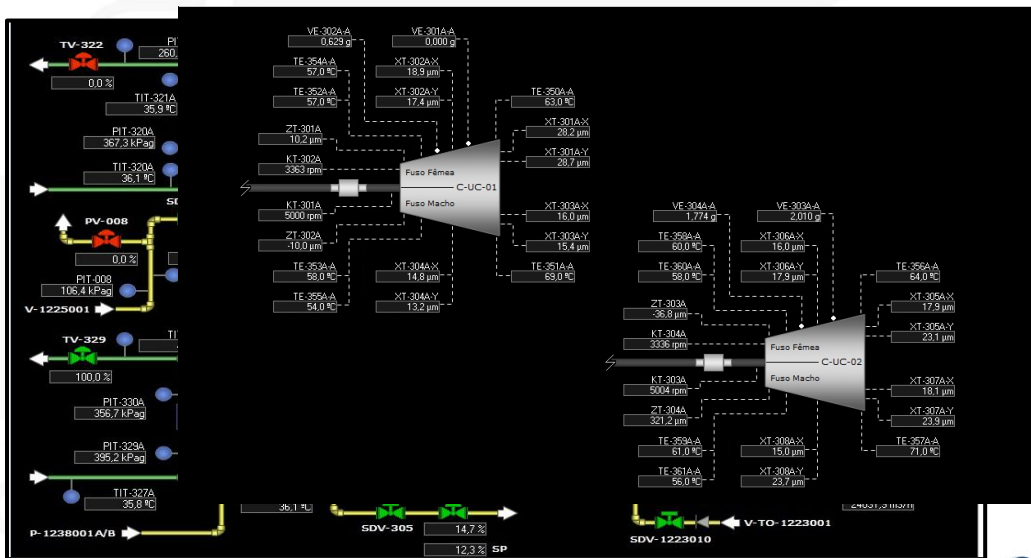
# Detector de Anomalías del Compresor de la Planta de Recuperación de Gases de Hidrocarburos

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## Recuperación de Gases de Hidrocarburos



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## Recuperación de Gases de Hidrocarburos

Estados de salud del **compresor**, incluyendo sus modos de fallas, presentan la siguiente distribución:

|                                       | value counts | normalized value counts |
|---------------------------------------|--------------|-------------------------|
| normal                                | 982519       | 0.981619                |
| Degraded State Falha de instrumento   | 4985         | 0.004980                |
| Degraded State Nível alto scrubber    | 4529         | 0.004525                |
| Degraded State Falha elétrica         | 3070         | 0.003067                |
| Degraded State Falha mecânica         | 2876         | 0.002873                |
| Degraded State Causa não identificada | 1739         | 0.001737                |
| Degraded State Pressão alta de sucção | 1199         | 0.001198                |

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## Recuperación de Gases de Hidrocarburos

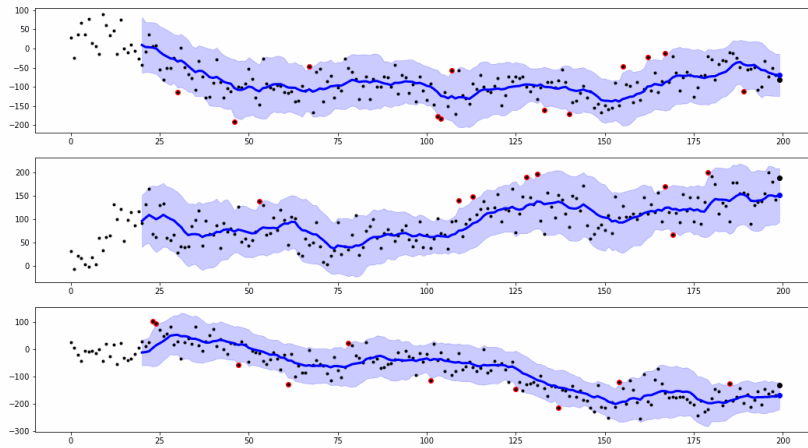
- El objetivo es detectar la falla temprana del **compresor**
- Está disponible el monitoreo de la condición de salud con las siguientes características:
  - Monitoreo por un periodo de aproximadamente 7 meses, desde el 15/Mayo/2019 hasta 30/Diciembre/2019
  - Son monitoreadas 27 variables del proceso con frecuencia de muestreo de 15 segundos
  - Los datos del monitoreo están en la base de datos adjunta en archivo CSV con 1,000,917 registros

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## Detector de Anomalías

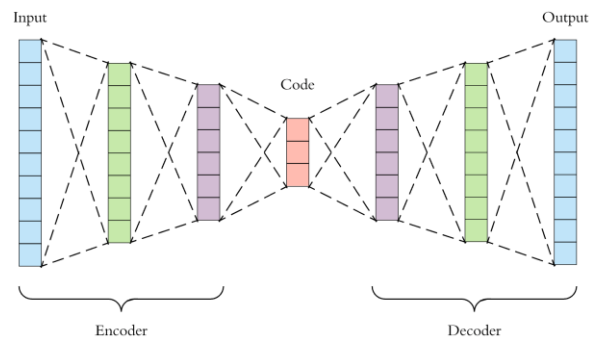
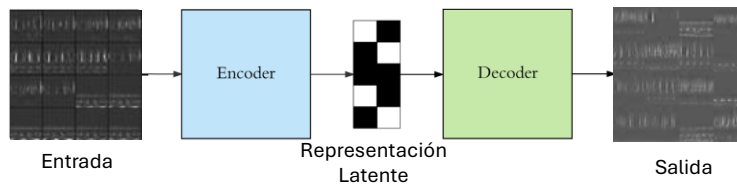


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## Detector de Anomalías



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# ¿Programar? ¡No!



```
%matplotlib inline
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
import itertools
from sklearn.metrics import confusion_matrix
from tensorflow.keras.models import Sequential, reshape, Conv1D, Input, Reshape, UpSampling1D, TimeDistributed
from tensorflow.keras.layers import Dense, Conv2D, MaxPooling2D, Flatten, TimeDistributed
from tensorflow.keras.callbacks import ModelCheckpoint
from tensorflow.keras.utils import plot_model

dataset = np.load('/Users/enriquelopez/Desktop/Neural_Networks/Neural_Networks_Prog.npz')
X_train = dataset['x_train']
X_test = dataset['x_test']
y_test = dataset['y_test']

input_layer = Input(shape = (36, 14))
encoded = Conv1D(filters = 32, kernel_size = 3, activation = 'relu', padding = 'same')(input_layer)
encoded = Conv1D(filters = 16, kernel_size = 3, activation = 'relu', padding = 'same')(encoded)

decoded = Conv1D(filters = 16, kernel_size = 3, activation = 'relu', padding = 'same')(encoded)
decoded = Conv1D(filters = 32, kernel_size = 3, activation = 'relu', padding = 'same')(decoded)
decoded = TimeDistributed(Dense(units = 14, activation = 'linear'))(decoded)

AE = Model(input_layer, decoded)
Encoder = Model(input_layer, encoded)

AE.compile(loss = 'mse', optimizer = 'adam')

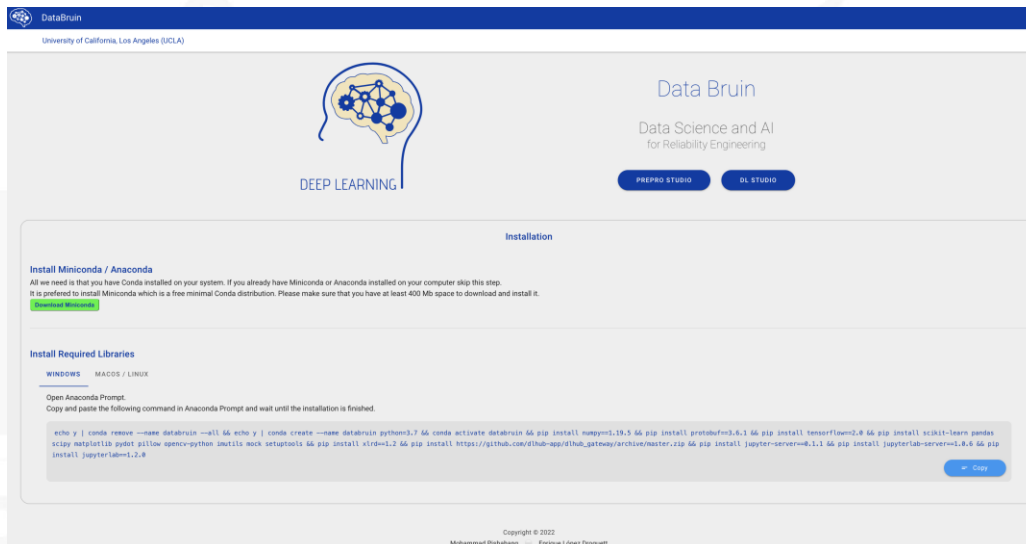
AE.summary()
```

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## DataBruin.com



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University of California, Los Angeles (UCLA)

**DEEP LEARNING**

**Data Bruin**  
Data Science and AI  
for Reliability Engineering

**PREPRO STUDIO** **DL STUDIO**

**Installation**

**Install Miniconda / Anaconda**  
All we need is that you have Conda installed on your system. If you already have Miniconda or Anaconda installed on your computer skip this step.  
It is preferred to install Miniconda which is a free minimal Conda distribution. Please make sure that you have at least 400 Mb space to download and install it.

[Download Miniconda](#)

**Install Required Libraries**

**WINDOWS** **MACOS / LINUX**

Open Anaconda Prompt.  
Copy and paste the following command in Anaconda Prompt and wait until the installation is finished.

```
echo y | conda remove --name databruin --all && echo y | conda create --name databruin python=3.7 && conda activate databruin && pip install numpy=1.19.3 && pip install protobuf=3.8.1 && pip install tensorflow=2.8 && pip install scikit-learn pandas  
scipy matplotlib pyplot pillow openpyxl python unetools mock setuputils && pip install xrt=2.2 && pip install https://github.com/dlhub-app/dlhub_gateway/archive/master.zip && pip install jupyter-server=1.1.1 && pip install jupyterlab-server=1.8.6 && pip  
install jupyterlab=1.2.8
```

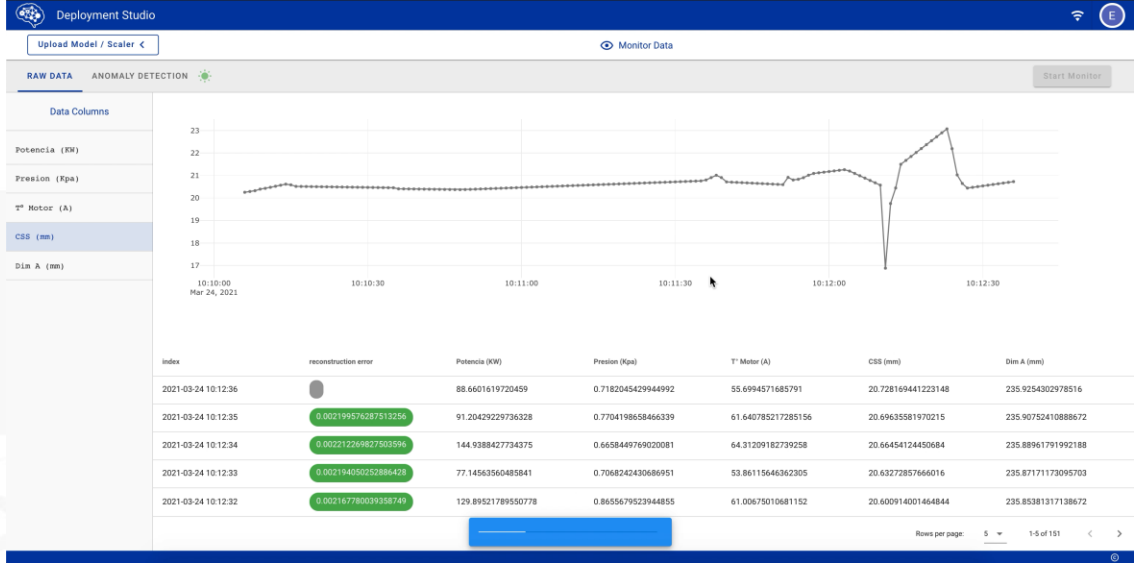
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Muhammad Pahalang Enrique López Droggett

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CONGRESO DE  
MANTENIMIENTO  
& CONFIABILIDAD  
COLOMBIA 2ª  
EDICIÓN

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# Dashboard



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# Demo en Vivo



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# iGracias!

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